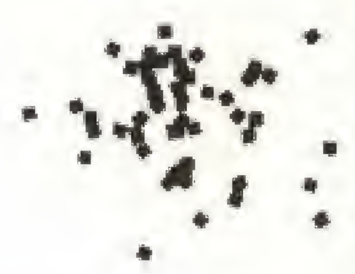
IBM Solid Logic Technology

Solid Logic Technology—SLT—is a microelectronic circuit technique developed by engineers and scientists at the International Business Machines Corporation's laboratories and manufacturing facilities in the Hudson River valley communities of Poughkeepsie and East Fishkill, New York.

SLT brings to microelectronic technology the kind of reliability that is borne of rigidly specified component values, precise circuit interconnections, and the manufacturing accuracy made possible by fully mechanized production.

With the development of SLT circuits and production techniques, IBM has made a major contribution toward applying microminiaturized electronics, on a practical basis, to data processing systems.

IBM System/360—a single system for business and scientific problem-solving—uses SLT in its logic and storage circuitry and benefits from the compactness, speed, and reliability provided by this technology.



The actual size of each transistor and diode on the cover is 28-thousandths-of-an-inch-square. These tiny "chips" are basic elements of Solid Logic Technology.

The Solid Logic Technology Concept

The "Solid" part of SLT refers to the microscopic transistors and diodes used in this circuit technique. These solid state devices act like vacuum tubes, but the electrical impulses travel through a solid material instead of a vacuum.

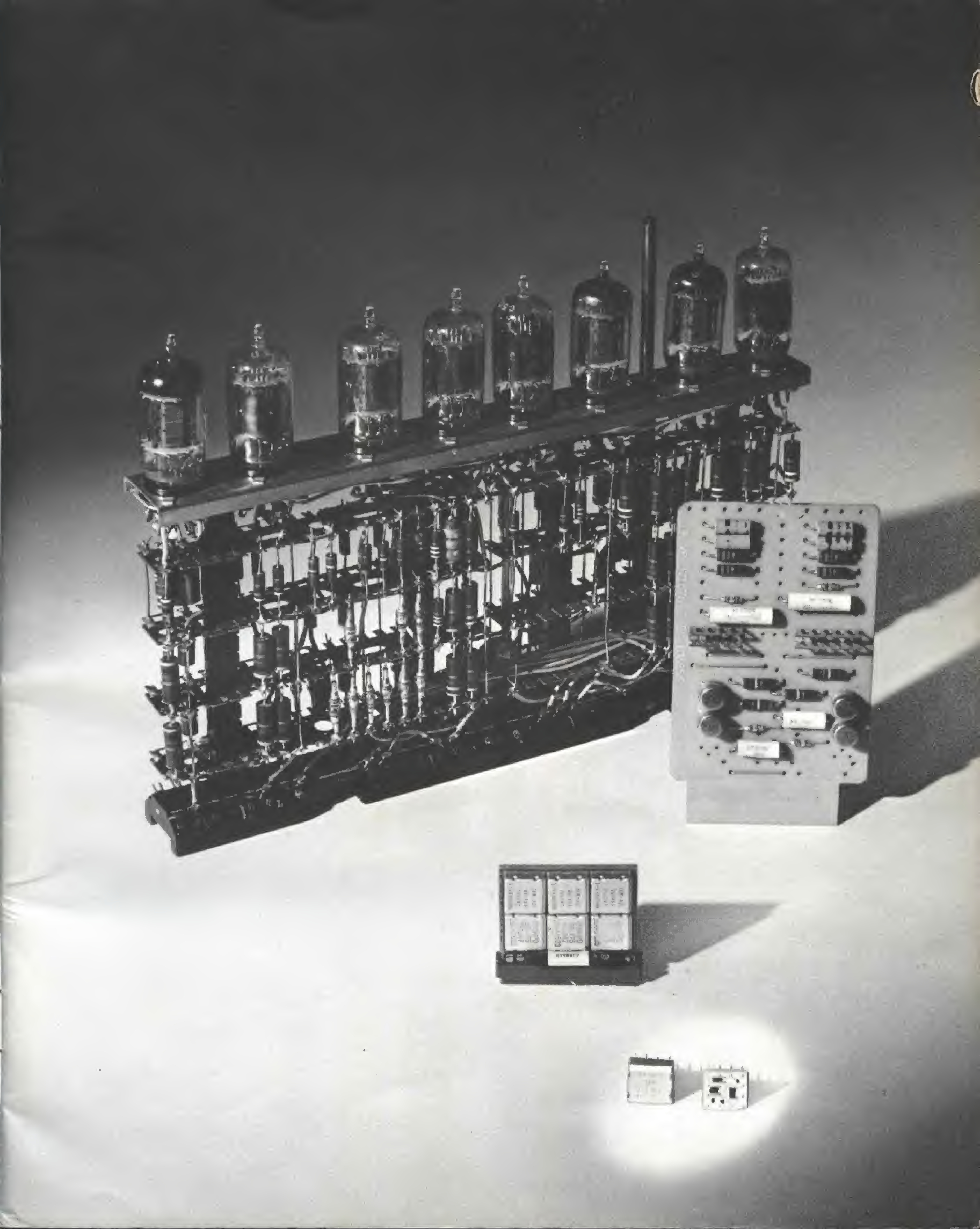
"Logic" is the function of the circuit module, individually and in combination with other circuit modules. Each has connectors, a circuit pattern, resistors, transistors and/or diodes.

When an electronic circuit is performing a logic function, it is switching, amplifying, and/or controlling electrical inputs to electronically calculate logic algebra. A computer's ability to solve programmed problems is, to a great extent, determined by the design of its logic circuitry.

Thus, through Solid Logic Technology, IBM engineers, scientists, and technicians have adapted a particular circuit concept to meet today's needs for high-performance, low-cost computer components.

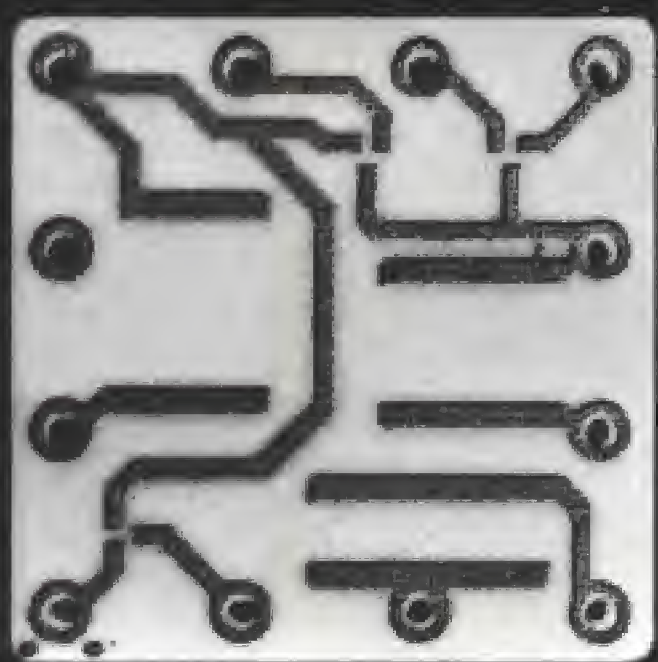
Progress in electronics has moved from the vacuum tube to the transistor to the tiny dot of an SLT "chip" transistor.

The assembly of circuit components (opposite page) for electronic computers began with the tube array (left) of over a decade ago. Next came the transistor technology (right) of the middle and late 1950's. In SLT (center), the technology is microelectronic—incorporating the tiny "chips" in half-inch-square circuit modules.

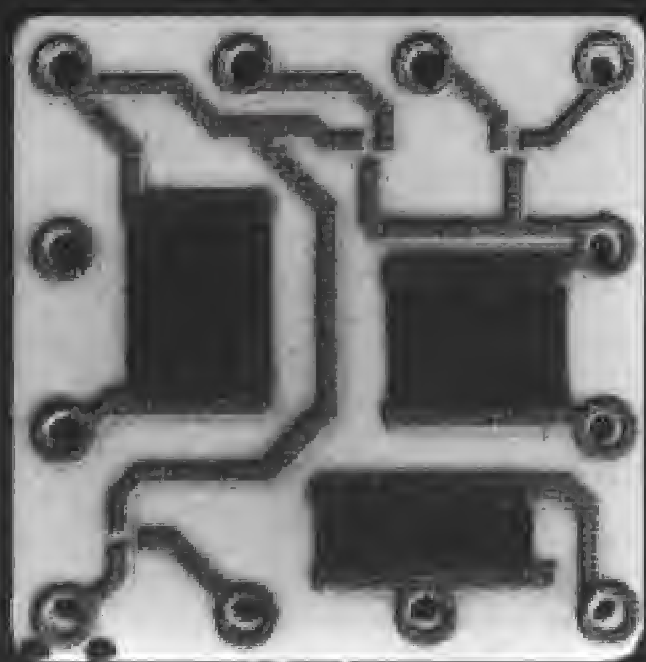


SLT Module Fabrication

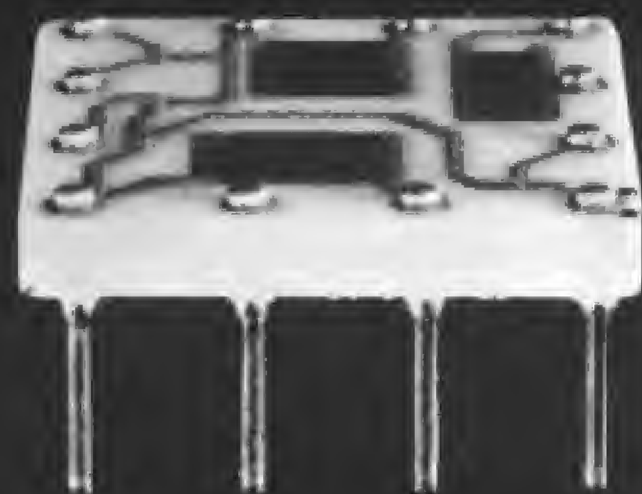
Bare substrate.



Print circuit pattern.

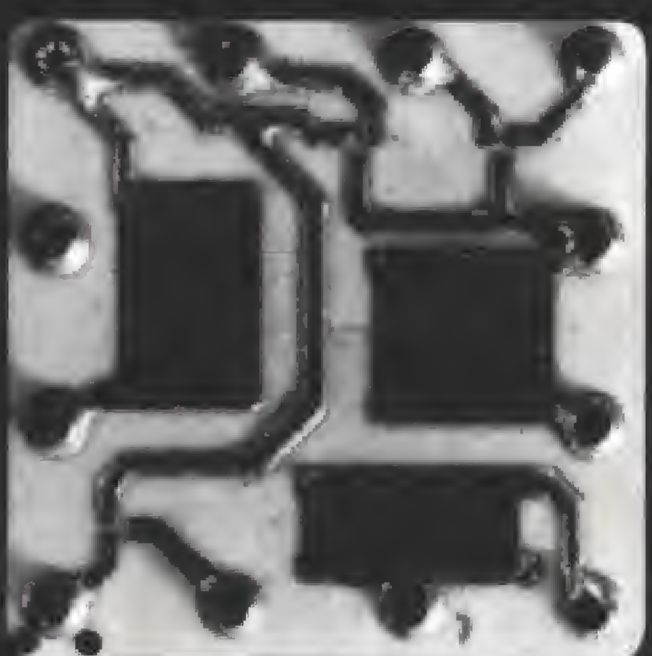


Print resistors.

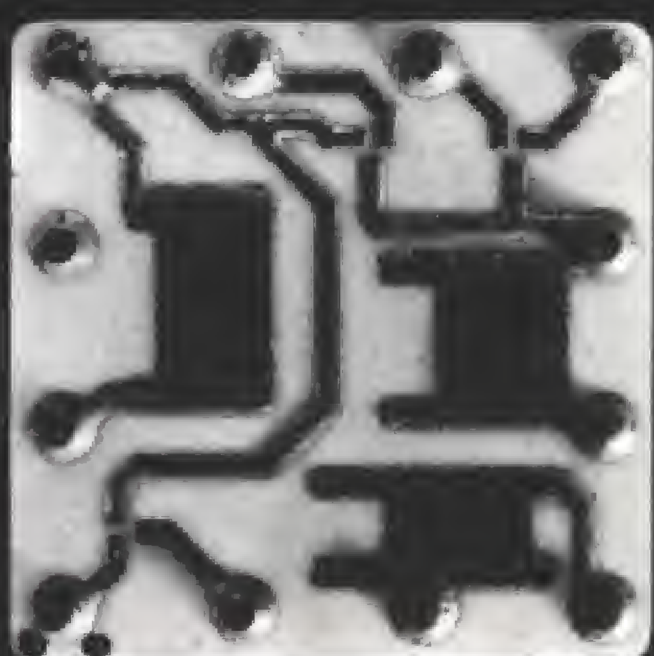


Insert connecting pins.

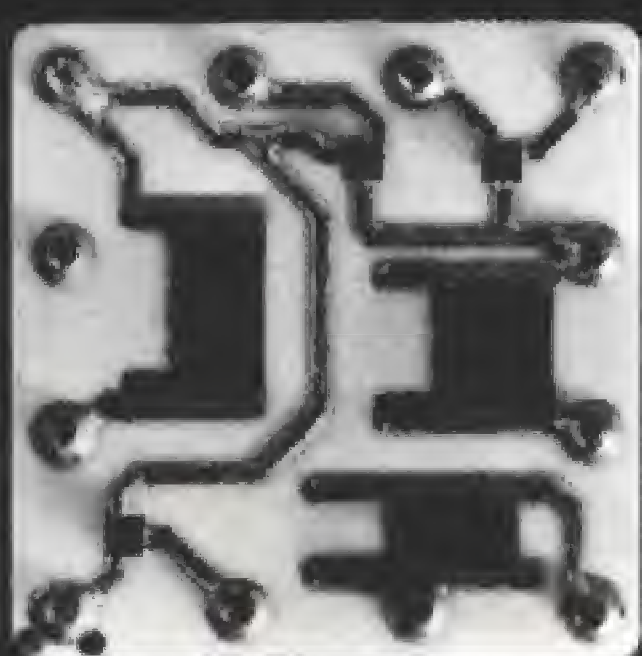
Dip into solder.



Trim resistors.



Attach chips.

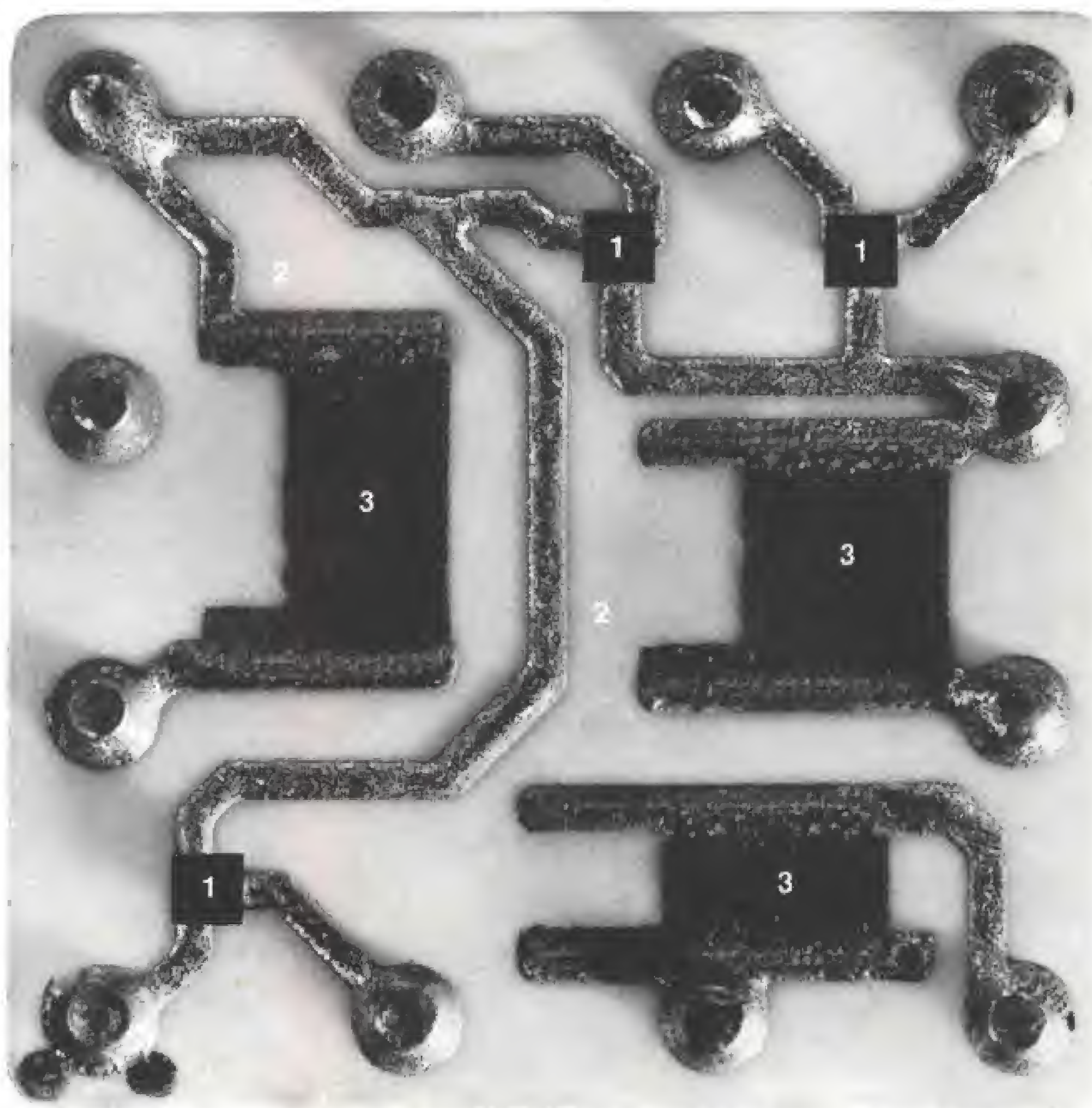


Seal in metal shell.

The basic electronic building block in IBM System/360 computers is the SLT module (actual size, left).

In the SLT manufacturing process (opposite page), a bare ceramic substrate (top left) is outfitted with a circuit pattern, resistors, and connecting pins. Then, the substrate is dipped into solder, resistors are trimmed, chip transistors and diodes are attached, and the unit is sealed in a protective metal shell.

*In an SLT module (below), the squares (**1**) are the tiny chip transistors and diodes which are attached at junctions on the circuit pattern (**2**). The large dark areas (**3**) are resistors. The two small dots at lower left are for orientation during fabrication.*



The actual size of the wafer (below) with more than 1,000 chip components. A photomicrograph of the wafer (opposite page) shows hundreds of completed chips—each with three metallic contacts.

The SLT Chip

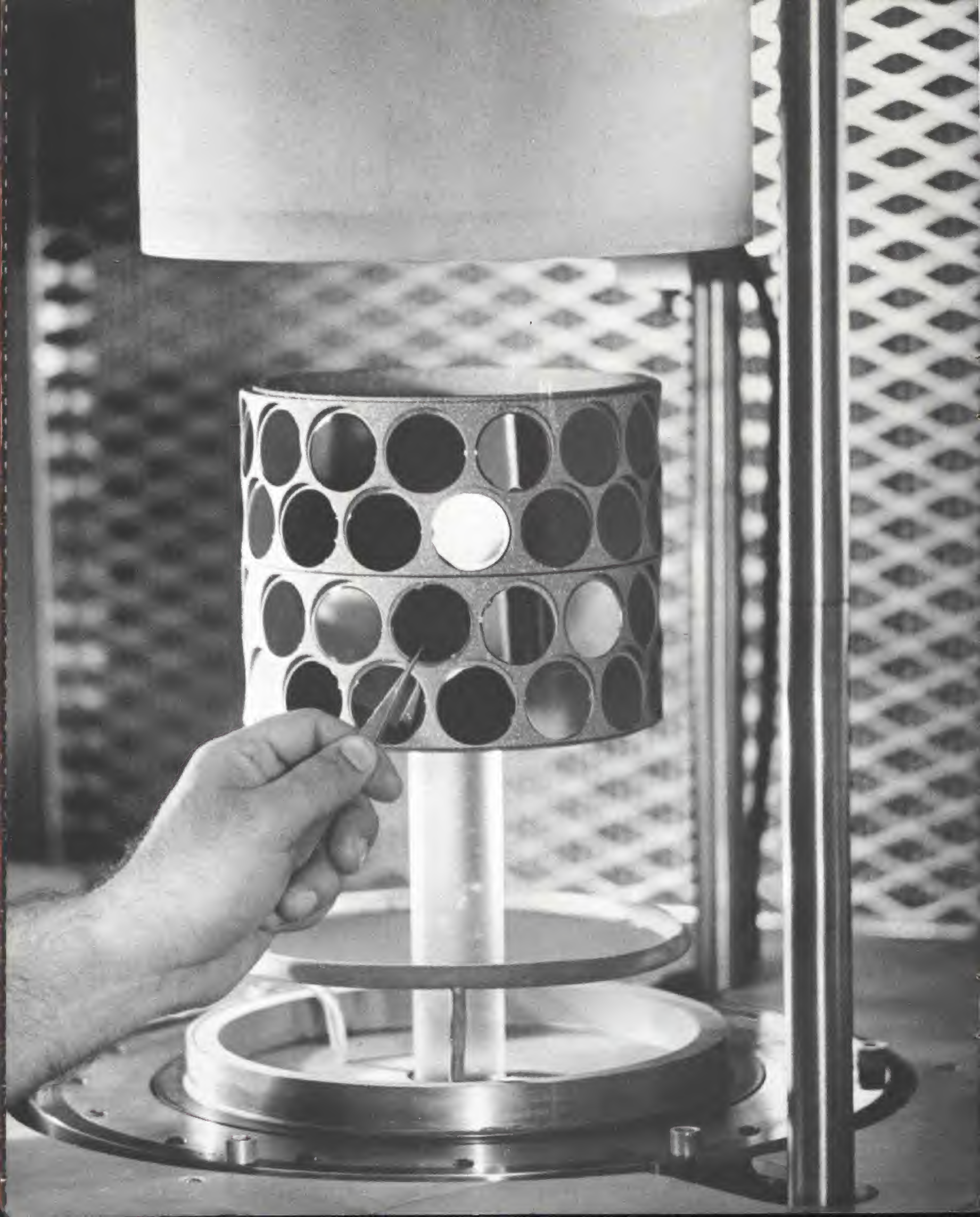
The tiny chip component of the SLT circuit is the single most significant development that led to incorporating this technology in general purpose data processing systems. Each transistor or diode chip is approximately the size of the period at the end of this sentence.

By existing technological standards, it is relatively easy to produce microscopic transistors and diodes . . . until you come to the problem of protecting the chip. The main accomplishment of the SLT chip is that it is protected by a thin coating of glass over the entire device (except for a metallurgical system which provides the electrical contacts). Ordinarily transistors are encased in a hermetically sealed, protective metal can.

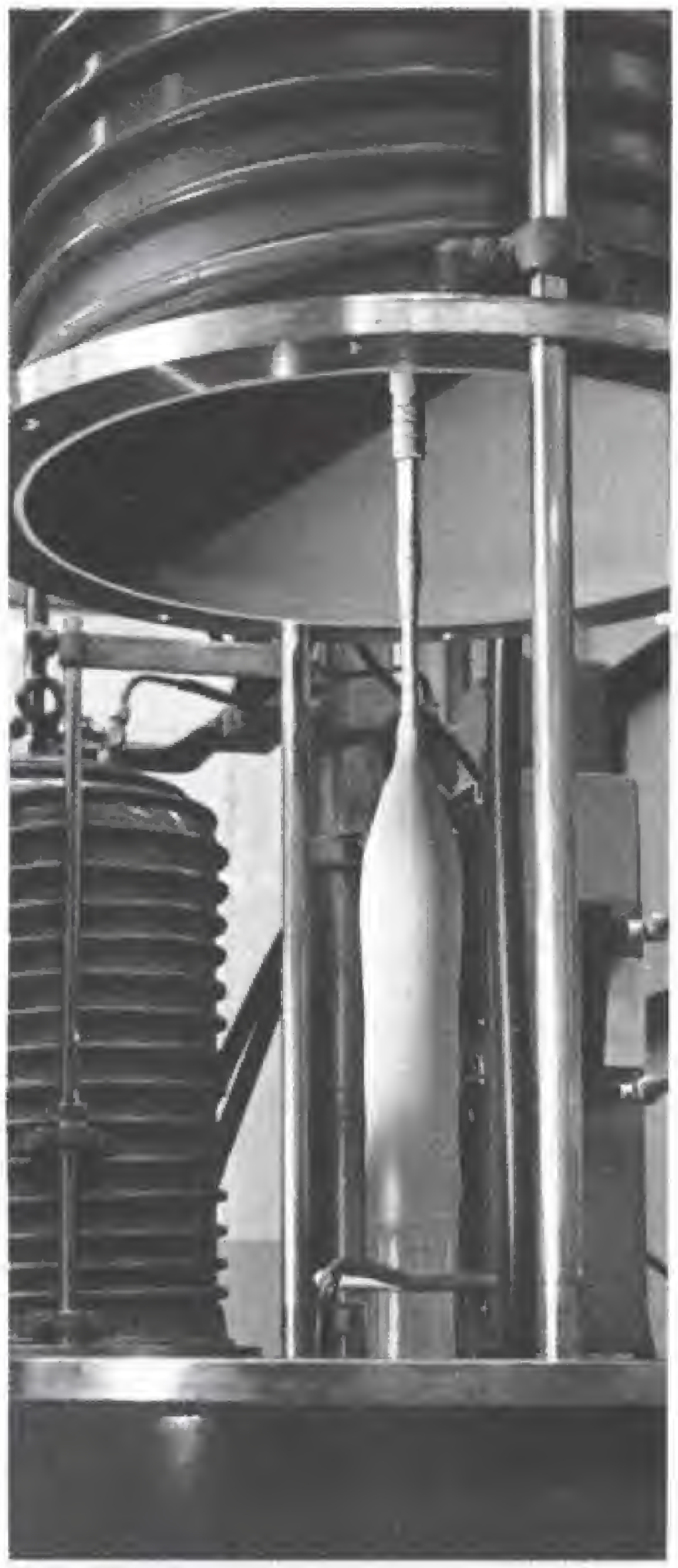
The chips do not need the metal cans, lead wires, whiskers, etc., that are used in fabricating conventional transistors. Additionally, fewer parts result in higher reliability.

In fabricating these chips, more than a thousand are made, simultaneously, on a 7-thousandths-of-an-inch-thin silicon crystal wafer about the size of a half-dollar. The chips are manufactured using vapor growth, graphic arts and photoprinting, diffusion, and evaporation processes to form the active regions and the contacts of the devices.

SLT transistors and diodes can be as small as they are because of a glassing operation which protects each device. After bonding a 60-millionths-of-an-inch-thin layer of glass to the surface of each wafer, they are removed from the furnace, ready for final process steps.



SLT Chip Fabrication

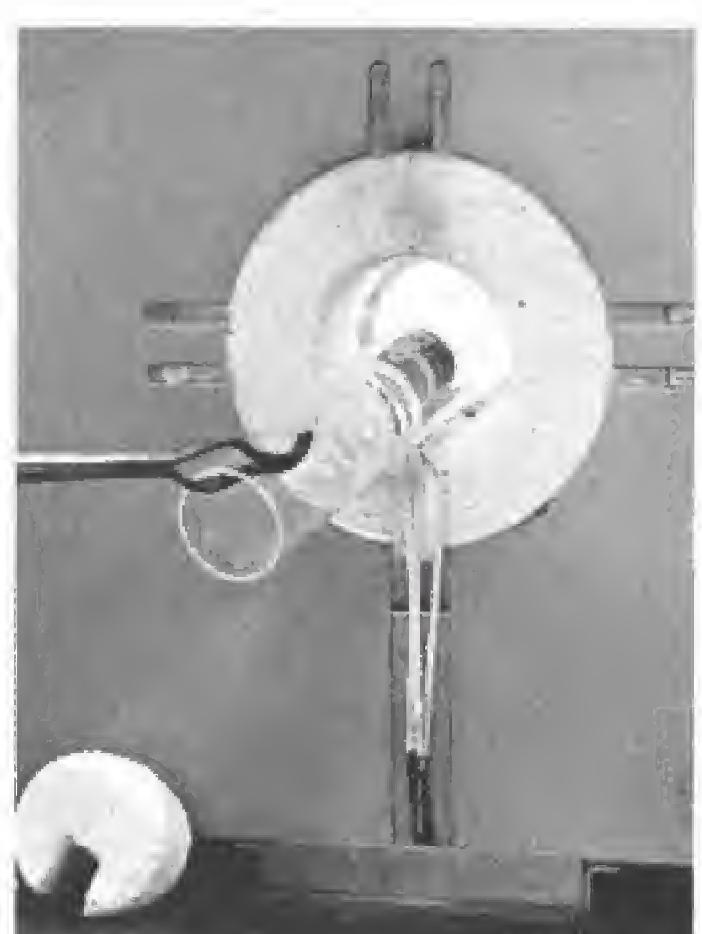


SLT wafers are cut from rods of silicon crystal which are grown in vacuum chambers (above).

A very thin layer of epitaxial silicon is vapor-grown onto the surface of the wafers in this high-production, "barrel-type" reactor (opposite page).

Areas which will become the electrical regions of each chip are photographically formed on the wafers (above, right).

Gas diffusion of the wafers takes place in a high-temperature furnace (right), which can process some 300 wafers at a time.

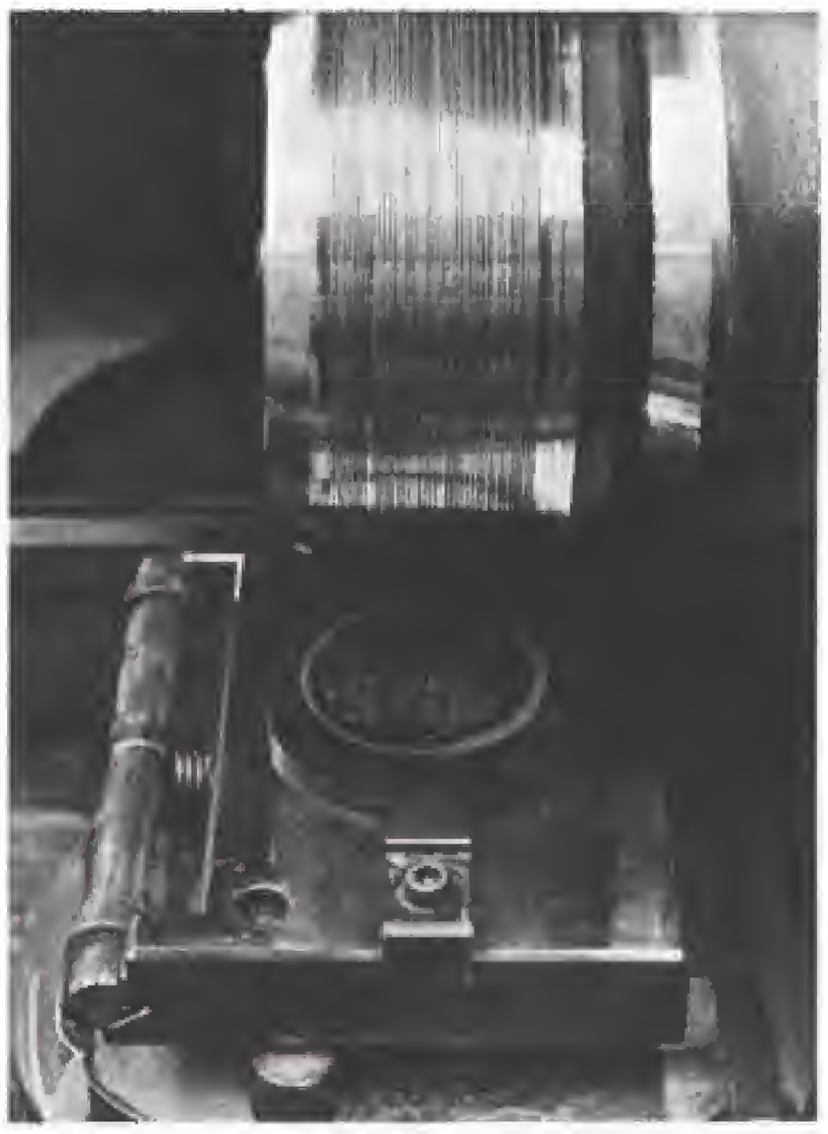


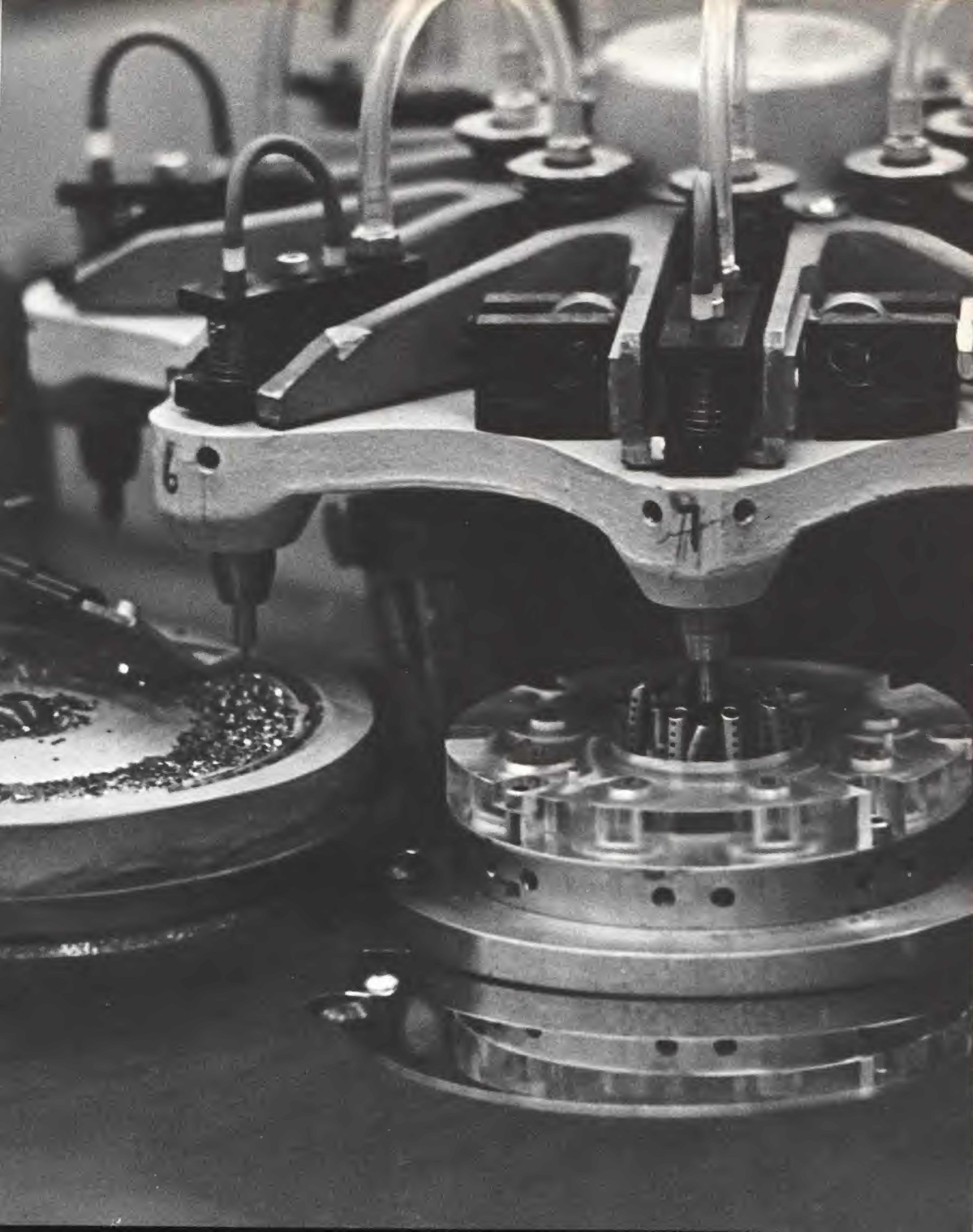
Wafers are removed from a vacuum chamber (top left) after metallic evaporation.

Tiny metallic spheres—about 5-thousandths-of-an-inch in diameter—are spread over each wafer (bottom left) to provide the electrical contacts between the circuit pattern on the module and the active regions of the chip.

After three spheres are joined to each device, a high-speed abrasive saw (below) dices the wafer into over 1,000 chips.

The final testing and sorting of each chip is done automatically (opposite page). In 3-tenths-of-a-second, a chip can be given as many as 40 electrical tests.





The SLT Module

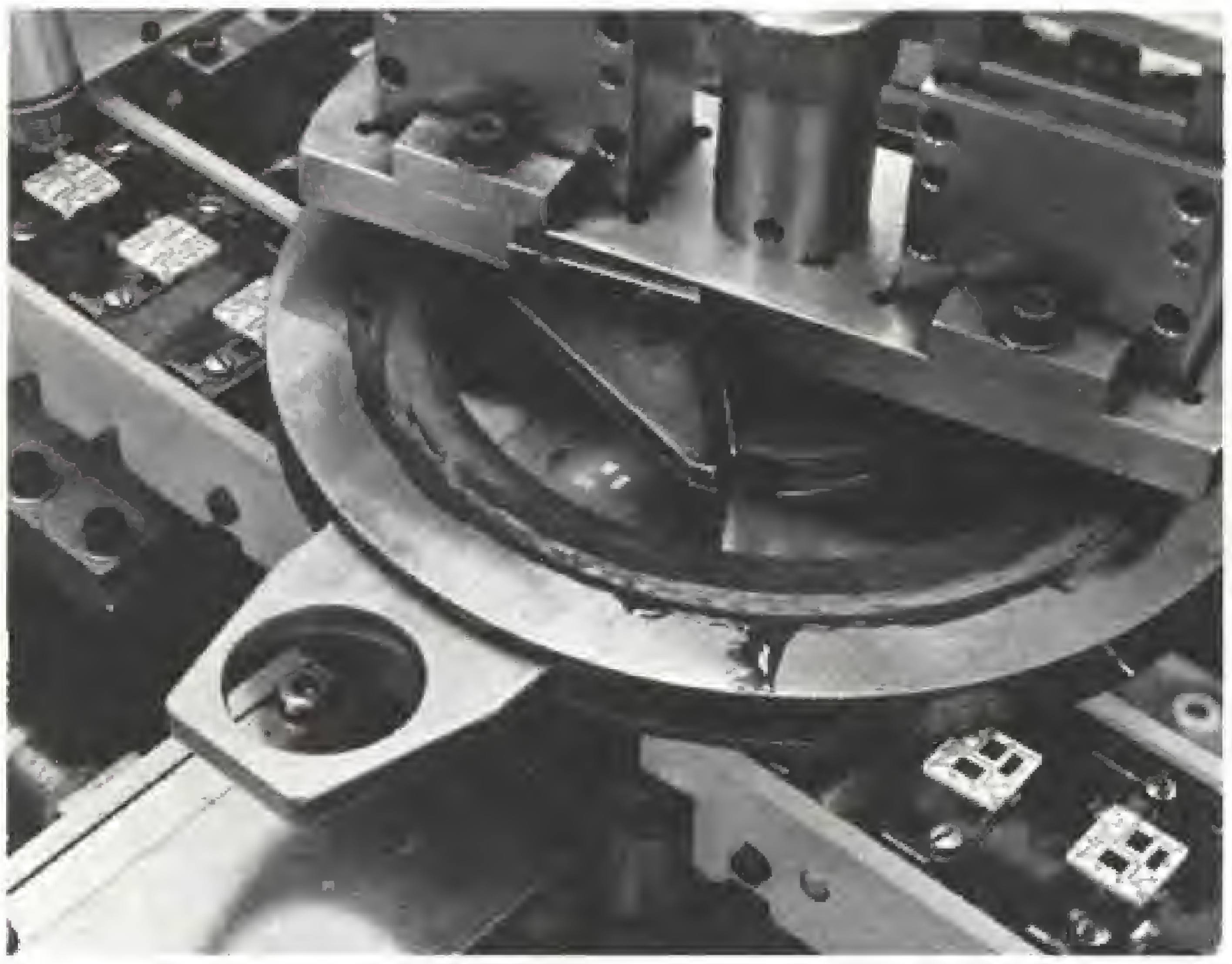
The SLT module is a circuit package which was designed to accommodate the microelectronic transistor and diode chips. These circuits serve as basic logic building blocks and as driver circuits for the storage units.

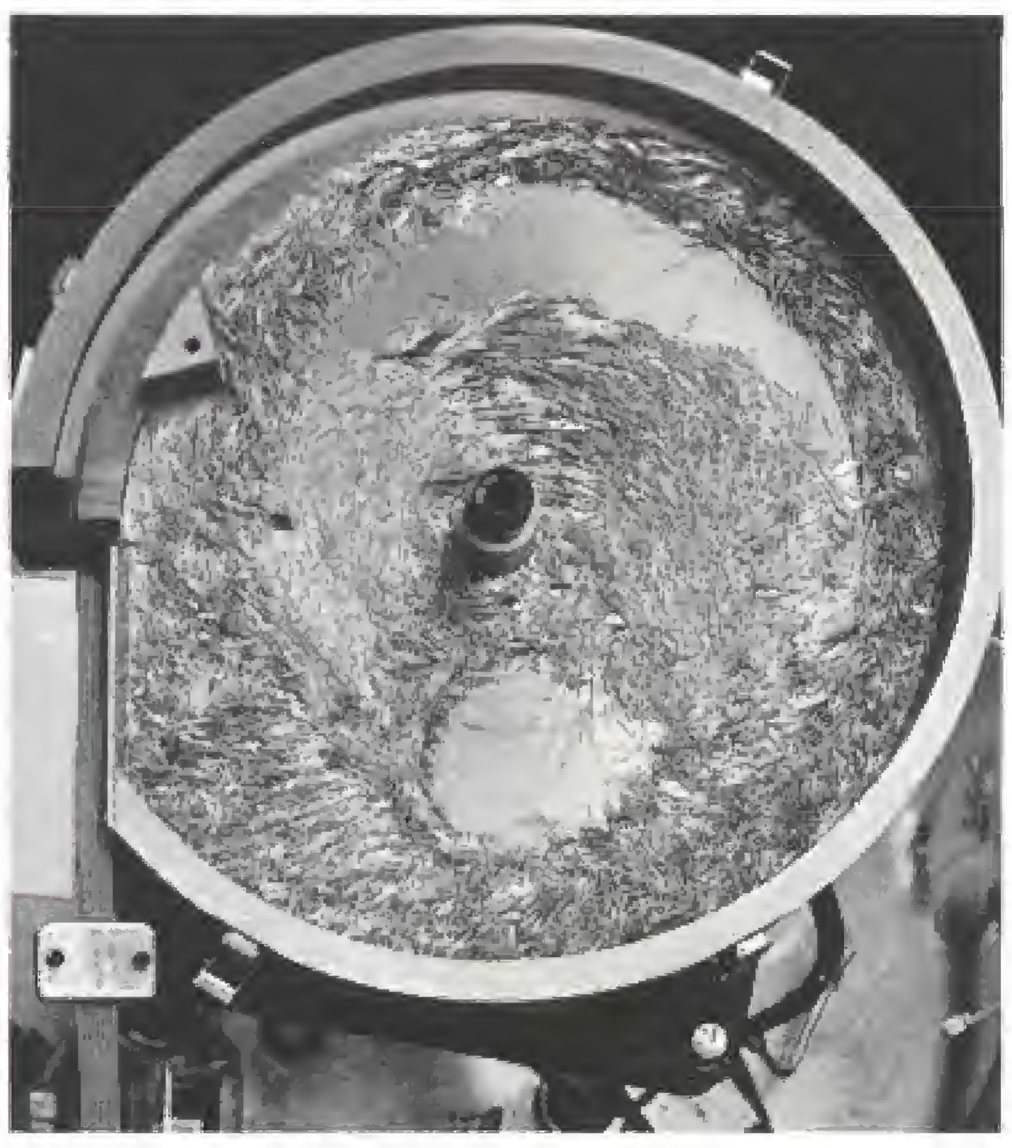
Each module is a ceramic square—measuring less than a half-inch on a side—which can carry a complete computer logic circuit. There are more than 40 different types of modules that handle inputs and outputs for basic and supporting circuit functions.

SLT modules do not require lengths of wire to connect electronic components or the myriad parts often associated with computer switching circuits. The fabrication of SLT modules is completely mechanized, using automatic equipment designed by IBM engineers. Circuit patterns and resistors are screen-printed onto the ceramic squares, 12 copper connecting pins are inserted around the perimeter, and the transistor or diode chips are precisely positioned by a specially designed machine. Then, each module is sealed in a protective aluminum shell.

The basic component, then, is the module. In order to harness its capabilities, it must be used as a building block in higher levels of circuit packaging.

Rows of SLT substrates (half-inch ceramic squares) are carried by conveyor belt into drying and firing ovens.





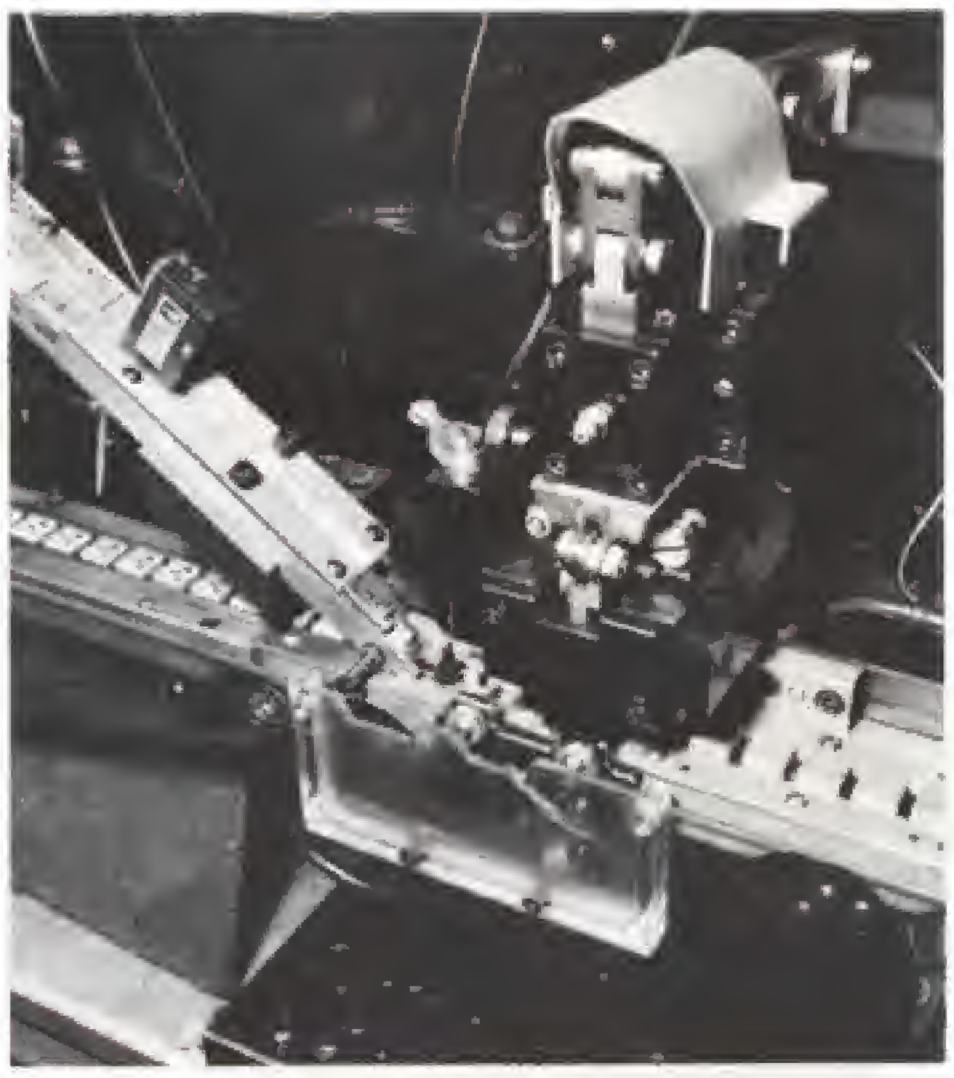
Circuit patterns and resistors are screen-printed onto SLT substrates (above, left) using a rotary head that "squeegees" special inks through a metal mask (or screen) to print the desired pattern.

As the screen-printing machine operates—at a rate of better than one substrate per second—the printed patterns are periodically inspected (above) to control ink flow and precise pattern registration.

Tiny copper connecting pins are fed by a vibrating bowl (left) into a machine that inserts the correct number of pins into each substrate at a rate of four substrates per second.

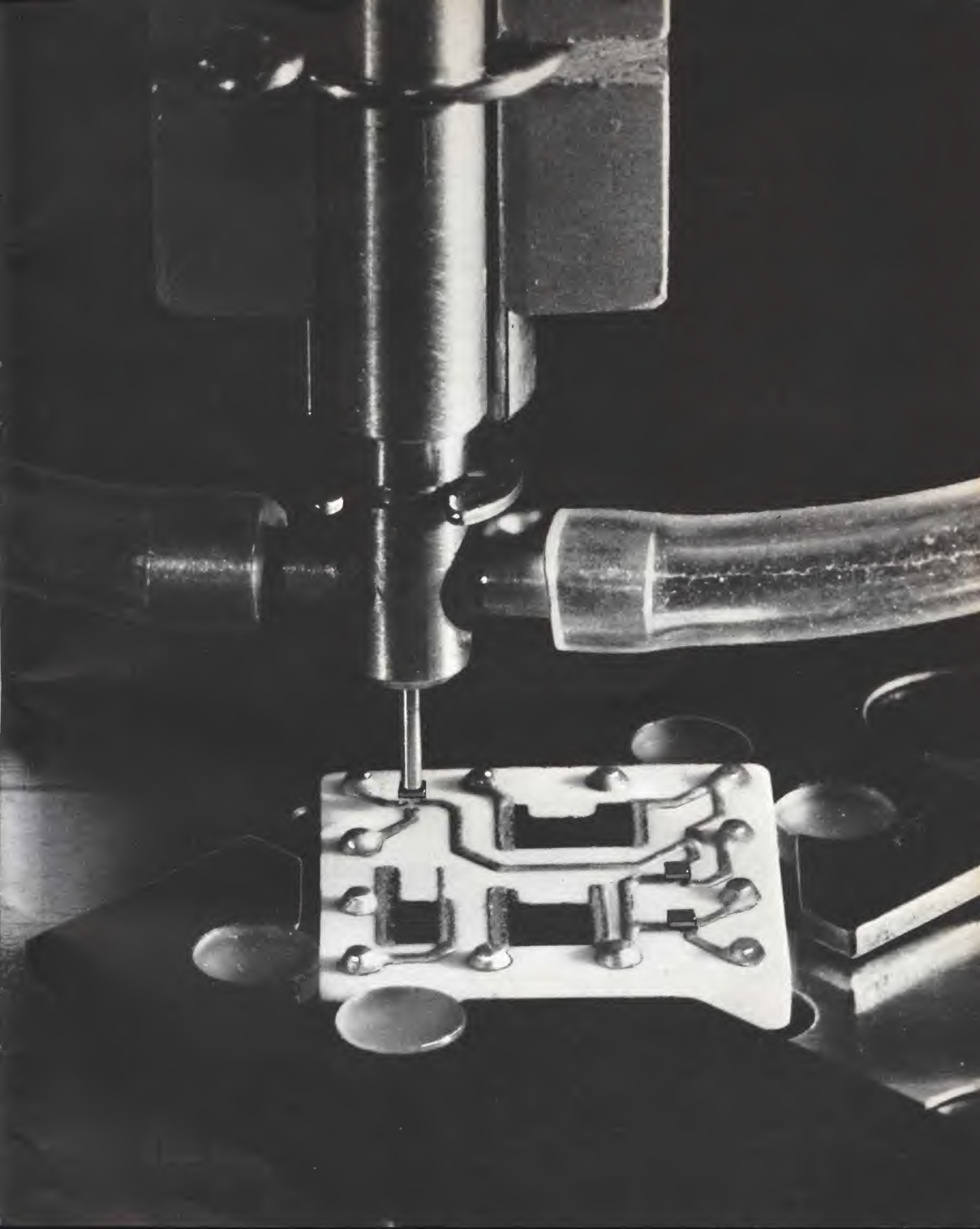
Hypodermic-like nozzles of the resistor trimming machine (opposite page) "sandblast" each resistor on each substrate (lower left) to tailor it to precise electrical value (resistance).


NATVAR



An automatic chip positioning machine (opposite page) completes SLT circuits, at a rate of better than one per second, by placing chips on specific locations on the substrates.

Final process steps are placing the completed substrates in their protective metal shells (left) and testing finished modules (below) for their performance characteristics.



The ASLT Module

For ultra-high-speed requirements, IBM circuit engineers developed the fastest logic circuits designed for scientific problem-solving.

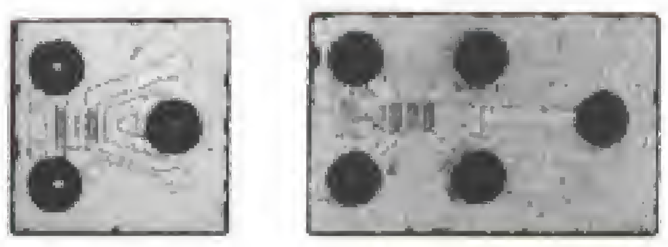
ASLT (Advanced Solid Logic Technology) modules incorporate many innovations in circuit design to meet the special demands of scientific data processing.

ASLT circuits can function in less than 1.5 nanoseconds (billionths-of-a-second)—about the time it takes light to travel 16 inches. This ultra-high speed is the result of the dense packaging of components on the substrates' tops and bottoms, the "piggyback" mounting of one substrate upon another, and the use of a form of circuit logic called current steering.

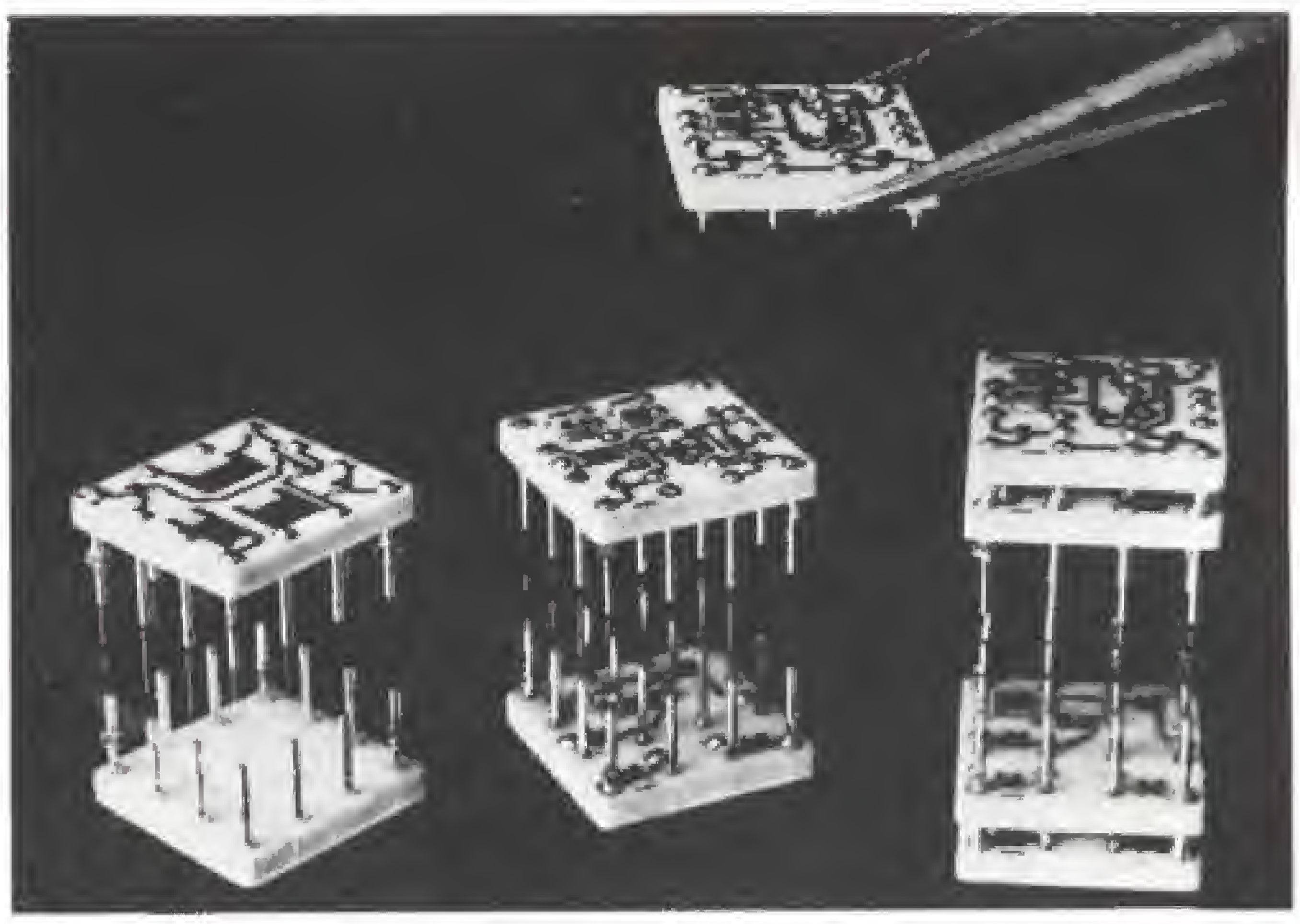
These densely packed "piggyback" circuits shorten the distance an electronic impulse must travel, cutting the time it takes to perform a calculation.

In current steering logic, no diodes are used, and electronic impulses are directed by ultra-high-speed transistors over one of two possible circuit paths. As the computer operates, current is always flowing through the circuit ("on" condition), rather than going from "on" to "off" in the course of a calculation.

In addition to advances in speed and circuit density, ASLT represents significant improvements in interconnection techniques, logical flexibility, wireability, and fan power—the number of other circuits with which a single circuit can communicate electronically.



Some of the chips (above) used in ASLT circuits contain two or three ultra-high-speed transistors but are only 50 percent larger than the single-transistor chips.



An SLT module and an ASLT module reveal their differences on a mirror. The ASLT module (right) contains circuit patterns, chips capacitors, and transistor chips on its top surfaces. Its bottom surfaces house circuit patterns and resistors. Soldered pins interconnect the "piggybacked" ASLT substrates.

The SLD Module

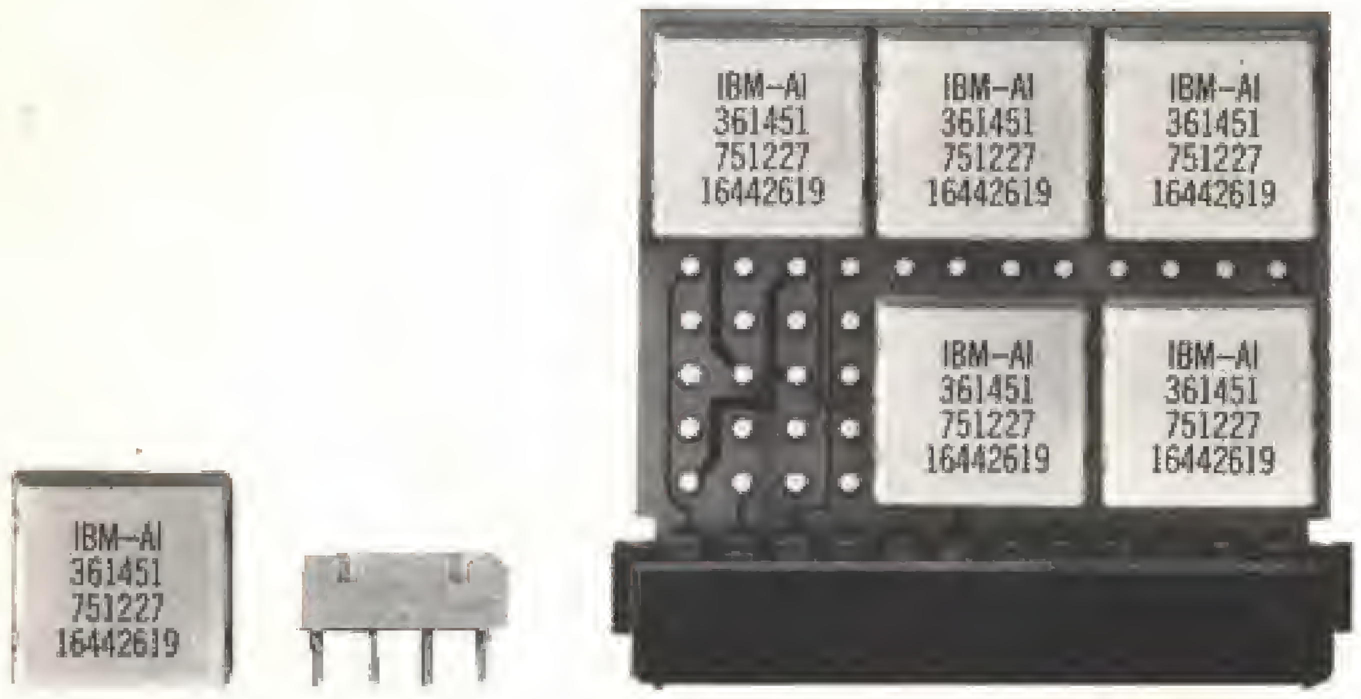
While one group of IBM engineers was working to increase the speed of SLT-type circuits and developed ASLT, another was devising ways of increasing the number of circuits on a single substrate. The result of this is SLD (Solid Logic Dense), a circuit technology in much the same speed ranges as the various SLT families, but with 2-5 circuits per module instead of just one.

The SLD module can carry as many as a dozen transistors and diodes (the same type as are used in SLT), and employs the same logic system as SLT. Much of the space saving is due to printing the resistors on the underside of the substrate, as is done in ASLT. SLD substrates, however, are not stacked.

Many SLD circuits are compatible with SLT, and cards of each can sometimes be interchanged. SLD, however, lacks the fastest SLT speeds, and has an additional 100 nanosecond family. Of particular practical value is the 700 nanosecond SLD series, which has found applications in operator-oriented machines where comparatively low speeds are desirable.

SLD has already been used in several IBM products where space was a more critical factor than speed. In the IBM Magnetic Tape "Selectric" Composer, for example, the logic section is made up of approximately 200 SLD modules. These occupy less than half the area of a comparable unit built with SLT.

Resting on the keys of an IBM Magnetic Tape "Selectric" Composer (MT/SC) are the half-inch-square SLD (Solid Logic Dense) microminiature circuit modules used in this typewriter-like composing machine. Each half-inch-square SLD module can contain from two to five complete circuits—including tiny (28-thousands-of-an-inch-square) transistors and diodes.



A pluggable printed circuit card (above) electrically combines six modules.

Cards are plugged into a board of a computer gate (below). Special cable is seen around the perimeter.

Circuit Packaging

An adaptable and flexible hierarchy of circuit packaging steps permits SLD, SLT and ASLT modules to achieve their logic and storage capabilities. These levels of packaging are the vital assembly steps that take microminiaturized circuits out of the realm of development and special applications and into the practical production of general purpose computers.

Modules are soldered to printed-circuit logic cards of various sizes in a manner determined by the particular performance desired. That is, these cards have circuit configurations that dovetail with the functions of the circuits provided by the modules.

Then, the logic cards are plugged into computer boards (in effect, larger cards) which have printed circuits on them and conform to the particular circuitry of the pluggable cards.

After completing these packaging steps, the computer boards are assembled into multi-board gates, which are interconnected by specially designed cables. The number of gates determines the logical performance capabilities of the computer. Varying packaging techniques are used for storage-logic and storage-driver circuits.

The cabling of the SLT gate provides another innovation in computer assembly. A flat cable, consisting of two layers of conducting wires each measuring 7-thousandths-of-an-inch in diameter, replaces the ordinary bulky cable.

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